

## QUALITY ASSURANCE IN BRIDGE SAFETY MANAGEMENT DATA COLLECTION

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### IMPORTANCE OF QUALITY INSPECTIONS TO BRIDGE SAFETY

The National Bridge Inspection Standards (NBIS) have been law for over 20 years. They were enacted by Congress because of a lack of uniformity nationwide in monitoring the condition of highway bridges. The incident that prompted the enactment of NBIS was the failure of the Silver Bridge in Point Pleasant, West Virginia, in 1967, where 46 people perished.

Clearly, the public's expectation for bridge safety is very high. In fact, when human life is at risk, the tolerance for bridge failure is zero. Bridge failures involving human life invariably evoke strong public reaction followed by enhancements in the law or in the specifications. Often the length of time between the catastrophe and the development of new requirements or guidelines tends to obscure the cause/effect relationship. For example, the Sunshine Skyway Bridge over Tampa Bay in Florida was struck by the bulk carrier vessel, Summit Venture, in 1980 which resulted in a catastrophic loss of life and bridge. A guide specification for protection of bridge substructures from impact damage by large ships was completed and recommended for inclusion in the AASHTO Design Manual in 1990. Examples of enhancements in the bridge inspection program prompted by publicized failures have included:

- The development of a Culvert Inspection Manual and Training Course after five people died from a culvert failure in Ohio in 1982.
- The development of a Manual and Training Course for the Inspection of Fracture Critical Bridge Members after the 1983 failure of the Mianus River Bridge in Connecticut where three lives were lost.
- The development of an underwater bridge inspection requirements and the implementation of scour evaluation criteria after the 1987 Schoharie Creek

Bridge failure in New York State where 10 persons were fatally injured.

- The failure of the Cyprus Street Viaduct and other bridge damage associated with California's Loma Prieta Earthquake in 1989 has provided stimulus for more stringent policy to identify potential problems from seismic damage.

Catastrophic failures not only provide impetus for changes in the standards, they create a significant disturbance within the agency responsible for the failed structure. Attention is immediately focused on the inspection practice; procedures and priorities are scrutinized by attorneys, politicians, and the media. Other serious problems include the loss of service of the structure, the loss of public confidence in the agency, the concern for litigation, and the threat of damage to individual careers.

The monitoring of quality is an important consideration in managing a bridge inspection program. While this will not guarantee safety it definitely improves safety and can help to ensure that limited resources available for bridge inspection are used efficiently. Certain critical elements should be checked closely each time the bridge is inspected. Other elements do not warrant as much time and attention. The agency that can demonstrate that available resources are used appropriately is in a much better position to defend their program if its is subjected to outside scrutiny.

The diligence and perseverance necessary to be a good bridge inspector is not present in every individual. Inspection involves looking at hundreds of details before finding a serious problem. Close-up inspection of all critical details is necessary. The work is physically demanding and access is difficult. Bridge inspectors often work at remote locations without senior supervision, and the accuracy of their work cannot be measured directly. How can the unit manager determine if an inspector is maintaining the proper level of intensity to identify the flaw that may lead to the fracture that results in the bridge failure? Quality in design or construction is easier to measure than quality in the inspection of an existing structure. With the inspection there are no calculations to check, no drawings to check, no testing reports to serve as documentation; only a report is created. Without reinspecting the bridge, it is impossible to verify the accuracy and thoroughness of the report. Most agencies recognize the need for quality inspections and the need to monitor the quality at more than one level.

The first level of quality is defined as quality control. Quality control is performed within a work group. (For the purposes of this paper, the work group will be a district bridge inspection unit within a state. It could also be a city, county, toll authority, or any work group within an agency responsible for bridge inspection.) We know that people make mistakes. Mistakes are a part of work. Members of an inspection team check behind each other. They review each other's sketches or descriptions, and they check for consistency of descriptions and measurements. Quality control is a necessary part of any production process. Quality Assurance (QA) is administered from outside the work group. The objective of QA is not to correct elements of a specific inspection report or load rating calculation. QA measures the quality of the work. The purpose of QA is to monitor and adjust the activity or program to assure ongoing levels of quality consistent with established requirements. Quality Assurance can also identify problems with quality control procedures.

#### IMPORTANCE OF QUALITY INSPECTION DATA TO BRIDGE MANAGEMENT

Poor quality bridge inspections influence more than the safety of the structures. Maintenance and repair priorities are established based on the data provided from inspection reports. Replacement and rehabilitation budgets are influenced by the inspection data. Certain federal money is allocated based on sufficiency ratings which are influenced by condition ratings provided by the inspector. The distribution of state and local funds may also be influenced by these ratings. The fairness and effectiveness of the repair and replacement program is influenced by the uniform interpretation and accuracy of the condition ratings.

Accurate inspection information also can help to maximize the service life of the existing structure. Timely maintenance is cost effective. Activities such as painting, waterproofing, and joint sealing can prevent costly damage to a very expensive structural system. No transportation agency has enough money. Spending should be based on accurate and complete information.

State DOT's are in the process of developing bridge management systems (BMS's) which will trigger maintenance, repair, and replacement actions. The BMS not only plays an important role in the management of a specific bridge, it influences

how systems of bridges are managed. Future deterioration rates are predicted by past changes in condition. This new tool improves the bridge engineer's ability to justify the funds necessary to support the most cost effective maintenance strategy. The implementation of BMS's increases significantly the need for more detailed, uniform, and accurate inspection data.

The Federal Highway Administration has an ongoing program to monitor the quality of state bridge inspection programs nationwide. A team from the FHWA Washington, regional, and state offices visit state DOT's to perform an evaluation of the inspection program. Their findings revealed shortcomings in the areas of agency oversight, quality assurance, and follow-up to the inspection. The FHWA findings recommend that the agency responsible for the bridge inspection program should have a formalized procedure to monitor the quality of the inspections. It is also important that the agency monitor their response to the inspection findings when a need is identified for maintenance, repair, or posting.

#### CURRENT METHODS OF MONITORING BRIDGE INSPECTION QUALITY

The NBIS program has evolved substantially differently in state DOT organizations nationwide. Some like Texas, Florida, Pennsylvania, and Ohio are decentralized with almost independent inspection units relying on the central office only for coordination and instruction guidelines. Others such as New Jersey, Delaware, and Alaska are basically single units responsible for the state inspections. Some units such as California, New Jersey, and New York have all graduate or registered professional engineer inspection team leaders. However, most states do not require "engineer" inspectors or team leaders.

In a few states, bridge inspection and evaluation is an independent DOT department; in others, it is a part of bridge maintenance. In most states, however, bridge inspection is a part of the bridge design department. A few states and most localities do not have full-time bridge inspectors. Their bridges are inspected by private consultants or in-house construction inspectors, designers, technicians, or maintenance employees as time permits. States and localities also differ in use of consultants and commitment of resources to the program.

The original purpose of the NBIS was to classify bridges according to serviceability, safety, and essentiality for public use, and to assign each an appropriate priority for replacement. The basic program was developed to apply to all states. As the program has matured, many states have expanded and enhanced their data collection system to provide additional bridge management needs. Bridge Management Systems (BMS) collect more detailed information on the condition of the bridge components. They prioritize, track, and document maintenance work as it is performed. Some BMS's categorize the structures based on a "level of service" concept. Most systems provide data for future scheduling and budgeting. No matter how complex the system, it is no better than the data provided by the bridge inspectors. QA is an essential part of a BMS.

Bridge inspection QA varies considerably between states. Among the states that place the most emphasis on QA are those that have experienced a catastrophic bridge failure. QA, like any other function, requires a commitment of time and resources. If it is administered as a low priority, "as time permits" function it will invariably be preempted by some other pressing activity.

A common form of bridge inspection QA activity is review of the inspection report by a supervisor. This procedure has limited value since it is not always possible to relate the completeness of the report with the accuracy or thoroughness of the inspection. This is particularly true of follow-up inspections where a prior inspection is being updated. Inspectors have been known to complete a report on an updated inspection without visiting the site. Hopefully this is a rare occurrence. It is more likely that shortcuts would involve a quick look at those problems that were identified during the previous inspection. This is a dangerous practice since critical problems can develop rapidly. There may be only one inspection cycle when the flaw is detectable by visual inspection before failure of the bridge. A QA review of the report can identify omissions or contradictions in the documentation. It may not be a reliable method to determine the quality of the inspection.

Another method of quality assurance that is often performed by agencies is for an observer to accompany the inspection team while they perform the inspection. There are some advantages and disadvantages to this approach. It provides an opportunity to ascertain, by observance, if the inspection team has the knowledge and

training to perform the inspection. The observer can ask questions to test the inspector's knowledge. It also provides an opportunity to evaluate the equipment available to the inspection team and if this equipment is used properly. The disadvantage of this approach is that it is unlikely to provide a representative example of the inspector's work. The individuals on the inspection team are unlikely to take shortcuts if they know they are being observed. This type of evaluation also tends to be subjective. The reviewer may be influenced by appearance, by attitude, or by knowledge that may or may not be a gauge of the quality of inspections performed on a day-to-day basis. These type of QA evaluations may be useful but they are not reliable in providing complete and objective results.

QA procedures have been implemented in several states. Our firm has been involved with the program implemented by DOT's in the states of Pennsylvania and Washington. Wilbur Smith Associates worked with both states to develop and implement their bridge inspection QA programs. The PennDOT program was developed in 1986 and has been ongoing since that time. The Washington State program was developed in 1992.

Pennsylvania has eleven decentralized districts with bridge inspection units. Counties and townships in Pennsylvania are also responsible for the inspection of their bridges. Currently, the PennDOT QA program monitors the state, local, and Turnpike bridge inspections. Wilbur Smith Associates performing the QA evaluations for seven years. The program is responsible for several enhancements to the state's bridge inspection guidelines and training. During the first four years there was a 50 percent improvement in the correlation between the district and the QA condition ratings since the program began. The correlation deficiencies averaged 10 percent when the program started. During the second round of evaluations they averaged less than 5 percent.

#### OBJECTIVES OF AN EFFECTIVE QA PROGRAM

For a QA program to be efficient it must include clearly defined procedures. The QA procedures should be performed at regular intervals in the same way each time. The procedures should be understood both by the reviewer and the reviewee. The procedures should be fair and unbiased. The purpose of QA is to improve the

bridge inspection program, not to point fingers at individuals. QA should be perceived as a constructive activity to improve the inspection program. For example, if the findings are used to reprimand or punish inspectors, they are likely to be perceived in a negative way. However, if they are used to identify needs for additional training, improved guidelines, or additional resources, they are likely to be perceived in a positive way. This is very important so that the findings will be taken seriously by the inspectors. A quality assurance program developed and presented in a constructive way can improve the quality of the inspections simply because of its existence. It must be perceived as fair in order to accomplish this.

The following components are necessary for a QA procedure to be perceived as fair by the bridge inspectors:

- the procedures are understood and accepted;
- the procedures are objective;
- the procedures provide quantitative results;
- the procedures provide accurate results;
- the procedures are administered uniformly and consistently during each review.

A totally independent field inspection performed by the QA team, where the findings are compared with the findings of the inspection team after the QA condition assessment is made, is more likely to provide objective results than comparing the inspector's current report while performing the QA inspection of the bridge. When a separate inspection is conducted, the QA team is less likely to be influenced by the previous findings. After the QA inspection is complete, the numerical condition ratings should be compared to the latest inspection report and deviations noted. It is suggested that the QA team then verify their decisions on any disagreements with the district's latest inspection report by reexamining the bridge element in question prior to it being reported to ensure that they can defend their findings. Acceptable tolerances should also be clearly defined. For example, on condition ratings greater than 4, a difference of 1 may be considered unimportant.

Procedures should also be clearly defined for the verification of inventory data, load posting data, and implementation of the inspection findings. As much as

possible, it is also desirable that the procedures provide quantitative results. Without quantitative results, it is difficult to compare findings. For example, which elements of the bridge inspection have more deviations between the QA and inspector's findings, or how do the different teams or different districts compare within the state? The quantitative measurements should reflect the number of deviations, the size of each deviation, and a weight factor reflecting the criticality of the item. Quantitative findings permit the inspection teams to measure their own improvement from year to year.

The accuracy of the QA findings is controlled primarily by the knowledge of the individuals performing the review. In other words, the QA reviewer must be very knowledgeable about the inspection standards and guidelines for the results to be credible. The reviewer must also be familiar with the training provided to the bridge inspectors. Ideally, the person performing the QA review is a registered professional engineer with considerable experience performing bridge related work including routine and comprehensive inspection.

Since many of the condition ratings involve judgement, it is important that the judgement be as consistent as possible. Funding allocations are influenced by the condition ratings. They should be the same statewide for the same conditions. For example, if a condition rating is in the range of 4, and the inspectors on one side of the state consistently call it a 3 while the other side calls it a 5, more funding is directed to the area that rates lower. If QA judgements are made uniformly, this problem may be identified and corrected. Uniformity and consistency are best attained by using the same QA evaluation team for all the reviews. Some changes are, of course, inevitable. However, they should be minimized, and the QA review team should be large enough to permit a new member to work with others while getting up to speed in providing uniform and consistent judgements.

Skills of diplomacy are also an important consideration in selecting individuals to perform QA. The QA role is to measure the report, not to criticize or direct. QA findings may influence policy and guidelines, but this should happen through the established chain of command. Policy should not be made or distributed by QA team members. QA should be performed in a manner so as to cause minimal interference with ongoing activities within the district.



## ELEMENTS OF THE BRIDGE INSPECTION QUALITY ASSURANCE PROGRAM

This section will cover the nuts and bolts of developing and implementing a bridge inspection QA program. The elements of the QA program will be described as follows:

- Planning and evaluation
- QA of the field data
- QA of the office data
- Remedial follow-up
- Findings per District
- Findings per Year

Planning the Evaluation: QA should include reinspections performed independently on a sampling of the bridges. The sample reinspections should accurately represent the bridge inventory. The sample bridges should be selected from those recently inspected.

Each year the districts should be visited in a different sequence to be determined in advance. Sample bridges are selected for QA for each district based on the distribution of bridge types in the district. The recommended sample size is 5% of the bridges inspected by the district teams during that year. The selection process is designed to provide a sampling that is a representative spectrum of all the bridges inspected that year. A profile of all the bridges in the district is developed first for use in selecting the samples. The features that are considered most important in the sample selection process are: type superstructure; total length; sufficiency rating; and district team performing the inspection.

It is important that the QA bridge inspection be performed soon after the district inspection is completed. Therefore, the sample bridges must be selected from those inspected within the last few months. The objective is to match the district's bridge population profile as closely as possible, selecting only from the group that was recently inspected. Beyond that the selection is random. Difficulty of access to the bridge because of size or location should not disqualify a bridge from inclusion in the sample group.

QA at the Bridge Site: The QA at the bridge consists of an independent verification of certain sensitive condition/appraisal items previously identified that remain the same for the annual cycle.

**Field QA Review Activities:**

- Verify and Identify the structure
- Photograph the structure
- Verify inventory data
- Take measurements for load rating check
- Verify traffic safety features and load posting signs
- Perform independent inspection of condition/appraisal items
- Compare with district ratings and reconcile, if possible
- Document findings
- List and prioritize maintenance/repair needs

Assessing the quality of the field inspection is a very important function of QA since deficiencies in this part of the program could impact the safety of the state's bridge system. The QA inspection should be performed with the same degree of thoroughness and intensity that is appropriate for the district's inspection. A hands-on, close-up QA inspection of the sample bridge based on the criticality of the element being inspected is therefore essential.

To save return trips to the field, it is recommended to compare the QA condition ratings with the inspector's ratings while at the site. It is best for the QA team to prepare an independent inspection report with complete documentation before comparisons are made. An alternative requiring less time is to only document out-of-tolerance findings. This approach involves rating the bridge elements, comparing the QA ratings with the district ratings, and documenting only the QA ratings that are out-of-tolerance. This requires the QA team to be provided with the district ratings prior to the review. The QA team also verifies certain inventory data details and dimensions to check load rating and posting information.

QA at the District Office: QA at the district office consists of verifying the availability and accuracy of the data on file.

Office QA Review focuses on the following:

- General file contents
- Inventory documentation
- Inspection documentation
- Proposed improvements
- Load rating analysis
- Follow-up documentation

The details obtained in the field are confirmed in the office. The file is also evaluated to determine how the inspection data is used. For example, were recommendations implemented, or was a new load rating analysis necessary? The QA teams should use a standard format to rate each item and comment as necessary. Each element of the office QA review is rated for completeness and accuracy.

A questionnaire is also completed during the office visit. This questionnaire is intended to monitor the district procedures. Often there are no specific procedural requirements, provided overall standards are met. However, it is helpful in evaluating the results to relate the effectiveness of procedures to the unique organizational structure of the district under review.

Remedial Follow-up: An important purpose of bridge safety inspection is to identify maintenance/repair needs and priorities. Part of the QA evaluation should focus on the accuracy of maintenance/repair needs identified by the districts and the procedures and documentation for implementing the work. If the agency has a bridge management system, the QA review should verify the utilization of this information in accomplishing and tracking maintenance/repair needs identified by the inspection.

Ideally, the inspection documentation identifies immediate problems, potential problems, and necessary maintenance to avoid future problems. The bridge safety inspection data base should include documentation that indicates the recommended improvements, a priority for each, and the dates that the work is scheduled and completed.

QA Review Report: The district is provided a report after each district QA

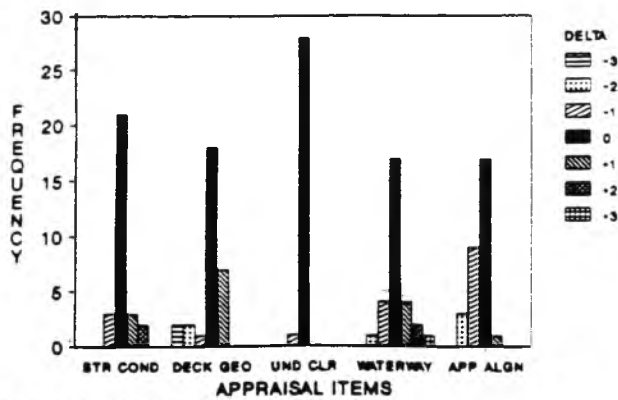
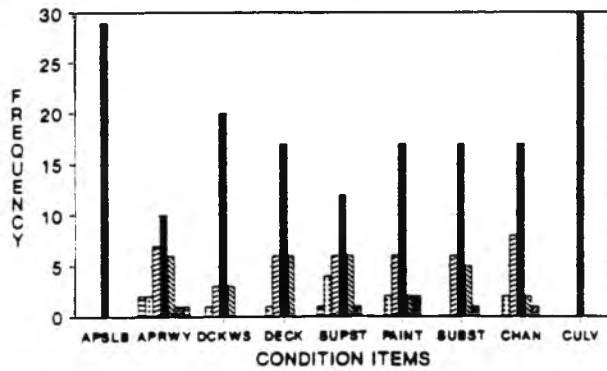
evaluation that provides the details of the findings. The district report is designed to provide a quantitative evaluation of the QA findings based on the accepted QA procedures. The same data is documented in the same order on each bridge review. The report provides a statistical correlation of the data. The data is organized so that areas of high and low correlation between the district and the QA team may be readily identified. The rating correlation between the district and the QA team is presented graphically with bar charts as shown in Exhibit 1. Unique findings are also listed. The report contains a section for a summary and conclusions. After the report is submitted and reviewed, a close-out meeting is held to discuss the findings and resolve any problems. If, after the close-out, the district does not agree with certain findings or conclusions they may respond with an addendum which is filed with the final report. Addenda by several districts on the same subject suggest a need to reevaluate the QA interpretation of the item in question and/or modify training course material.

Annual Report: The annual report contains a summary of all QA activities performed for a given year and a comparison of these findings statewide. In this report bar charts for each inspection team are arranged so that all the district results are listed side by side. An example of this is included in Exhibit 2. This format is helpful in identifying inspection items that have received a wide range of ratings for a given condition. This information is helpful in identifying possible needed enhancements in the inspector's training information or the guidelines. If deviations are experienced for a particular item in just one district, it is more likely an internal problem. Exhibit 3 shows how the QA results can be evaluated over a period of several years,.

The annual report also includes a narrative summary of the findings per district with details of their resolution at the close-out meetings. There is a section on conclusions that identifies areas of concern based on the overall findings.

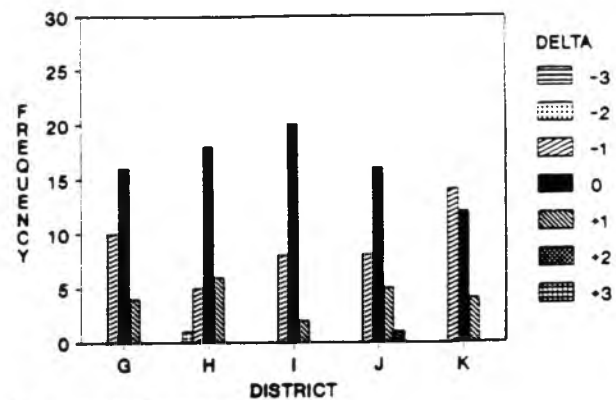
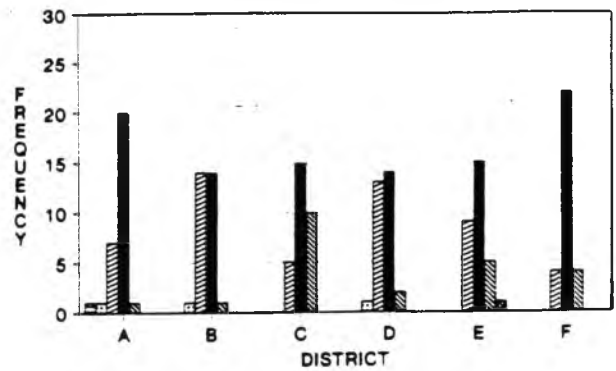
There is also a section on recommendations for the next year. This section proposes modifications in the program based on the annual findings. If there are improvements warranted in the QA procedures these are also recommended. This section might also contain suggestions for improvements in the statewide bridge inspection guidelines or inspector's training.

**EXHIBIT 1**  
DIFFERENCE BETWEEN QUALITY ASSURANCE  
REVIEW AND DISTRICT A RATINGS  
1989



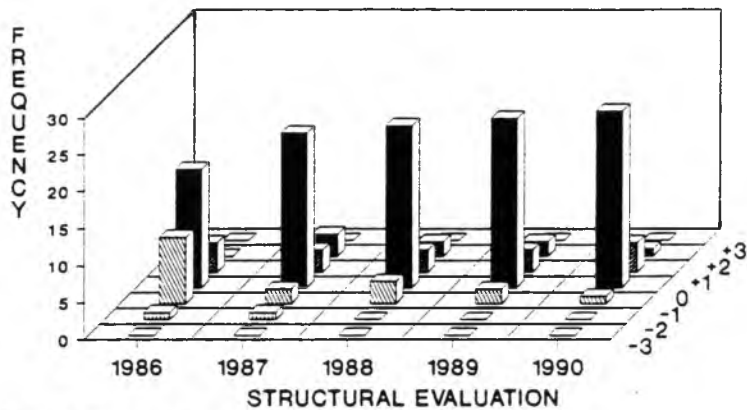
NOTE: + Indicates District rating greater than review

**EXHIBIT 2**  
'86 DIFFERENCE BETWEEN QUALITY ASSURANCE  
REVIEW AND DISTRICT RATINGS STATEWIDE  
STRUCTURAL EVALUATION



NOTE: + Indicates District rating greater than review

**EXHIBIT 3**  
DIFFERENCE BETWEEN QUALITY ASSURANCE  
REVIEW AND DISTRICT RATINGS



NOTE: + Indicates District rating greater than review